Quality Improvement Through Consumer Sorting and Disposal

Peyton Ferrier
United States Department of Agriculture, Economic Research Service, Washington, DC. E-mail: pferrier@ers.usda.gov

ABSTRACT

Sorting allows consumers to capture the value of quality differences. As higher quality goods are removed, the value of the seller's remaining stock falls, lowering the price and profits. Bundling and other marketing mechanisms can discourage sorting and prevent the depreciation of the seller's stock. With comparative statics and simulations, the author shows that sellers can increase expected quality and profits by committing to discard a proportion of their resale stock after sorting occurs. In this manner, sorting acts similarly to agricultural grading. [EconLit Classification: Q1, Q11, Q13, L0, L1, D8, D82]. © 2009 Wiley Periodicals, Inc.

1. INTRODUCTION

Even when sold at one price, agricultural goods sold at the retail level often vary in quality. With the value of quality differences left in the public domain, consumers sort goods to capture some of that unclaimed value. However, if the distribution of qualities is fixed, sorting only redistributes qualities. As consumers sort, they lose time and effort and reduce the value of the remaining goods, but do nothing to improve the average quality of the goods available for sale. Barzel (1977, 1982) argues that, to prevent this welfare loss, sellers will design marketing mechanisms to discourage sorting. For example, sellers may bundle or have attendants distribute produce.[1] Despite this motivation, mechanisms to prevent consumer sorting at the retail level seem rare. Why do retailers allow it? Here it is argued that when the assumption of market-clearing is relaxed and sellers dispose of a portion of their product, consumer sorting acts similarly to agricultural grading to improve expected quality.

This article presents a model of consumer sorting with disposal that incorporates consumer heterogeneity in both preference for quality and the cost of sorting. With comparative statics and simulations, disposal is shown to increase when expected quality is responsive to small changes in disposal (i.e., when the distribution of quality is more variable or skewed primarily towards high qualities), when consumer preferences are heterogeneous, and when wholesale costs are low relative to resale prices. Sellers can discourage sorting through various marketing practices (i.e., having attendants disperse goods or bundling) or by increasing the uniformity of their products. Understanding how disposal is used by sellers is important to understanding the linkage between wholesale disappearance and retail sales of

[1] For example, Produce Junction Inc. has handlers disperse all its produce at its 15 stores in Pennsylvania and New Jersey (Produce Junction, 2009).

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agricultural goods. As more goods are thrown away, expected quality increases. In contrast with the prediction of the Alchian and Allen's well-known theory of "shipping the good apples out" (Borcherding & Silberberg, 1978; Alchian & Allen, 1964). If wholesale and transportation costs are lower, retailers discard goods and sell higher qualities. In the extreme, if wholesale costs are zero, retailers would only sell the highest quality portion of the distribution and consumers in areas with very low wholesale costs (such as those near the actual farms where produce is grown) consume higher-quality goods.

2. LITERATURE REVIEW

The presentation and packaging of fruits, vegetables, and nursery crops uniquely invites consumer sorting. Physically touching and examining these products provides the consumer with haptic information that can build consumer trust in a product's quality (Peck & Childers, 2003a,b). Moreover, the quality of produce and nursery products is variable. Blemishes and damage can appear on individual items, making them unattractive and difficult to sell. Although retail shrink and loss are readily understood among producer retailers, little research informs how consumer sorting and disposal interact with the expected quality of a consumer's purchase, despite the prevalence of farmers markets and pick-your-own outlets that seem to encourage sorting.

Retail shrink describes the portion of the wholesale stock that goes unsold at the retail level. Table 1 shows the decomposition of different forms of retail shrink (Major, 2005) which, in total, ranges between 5 and 6%. The two categories, "Overordering" and "Improper handling…" are particularly high for produce and floral products, representing approximately a 2% loss for each. Similarly, Kantor, Lipton, Manchester, and Oliveira (1997) estimate that approximately 2% of the total produce, went unsold at the retail level in 1995. The Economic Research Service (Buzby et al., 2009) estimates retail food loss for fresh fruits as 11.4% and for fresh vegetables as 9.7%. Though these percentages are still small, anecdotal evidence suggests that loss rates are higher at premium supermarkets and little revenue is recovered on unsold produce and nursery crops. Also, food loss is higher for certain goods with less durability and more quality variance. For instance, potatoes and dried fruits are much less susceptible to decay and loss than bananas, tomatoes, melons, and flowers. Ironically, produce may also be damaged by the act of sorting itself, which may create the quality differences that lead to sorting in the first place.

Sorting also creates an opportunity cost in terms of the consumer's lost time and effort. Barzel (1977, 1982) argues that sellers can restrict sorting through various marketing mechanisms including bundling, which reduces the variance in quality of any item purchased. Barzel showed that when consumers are homogeneous in their preferences for quality, sorting cannot increase allocative efficiency, but can only reduce the gains from trade by creating these additional opportunity costs. By reducing the variance in quality at the point of sale, bundling reduces the potential value of the quality differences that could be captured from the public domain, which is the return to sorting. Similar rationales have been cited for diamonds and first-run movie showings (Kenney & Klein, 1983), timber harvest rights (Leffler & Rucker, 1991), and produce (Leffler, Malishka, & Rucker, 2001). Undoubtedly, other motivations for bundling remain, including logistical (i.e., easier movement),

TABLE 1. Sources of Perishable Shrink for Various Fresh Foods

	Meat (%)	Seafood (%)	Produce (%)	Floral (%)	Bakery (%)
Overall shrink	4.68	4.92	5.02	6.24	6.05
Components					
Employee theft	12	9	11	19	24
Cashier theft	20	12	21	13	15
Receiving damage	3	9	6	9	5
Pricing, scan file errors	7	11	8	7	6
Shoplifting	23	20	12	14	11
Overordering	12	15	15	16	7
Improper handling, space allocation, overproduction, throwaways	23	24	27	22	32

Note. Source: Data from Major, 2005.

liability concerns and quality control (i.e., consumer damage, contamination, or slip-and-fall concerns), and market power (see Nalebluff, 2003 for examples).

Yet sorting remains common with produce and nursery products due to the good's underlying quality variability. Stivers (2006) shows that marketing costs can limit the number of quality grades offered where each grade represents a range of qualities. When quality variability is present, sellers must then choose to what extent to allow sorting. In conjunction with disposal, sorting may raise expected quality when the unsold stock is reliably of the lowest quality. In short, a store that discards its remaining produce and restocks when the bottom 10% remains has a higher expected quality than a store that replenishes at 5%. For sorting to be profitable, this higher expected quality must allow for a more-than-commensurate price increases. By opting to discard the lowest quality goods, retailers leverage the consumer's ability to distinguish quality even if they themselves cannot distinguish it.

3. MARKET CHARACTERISTICS OF SUPPLY AND DEMAND

To consider the effect of sorting, we use a vertical differentiation model of demand (Laffont & Martimort, 2002; Mussa & Rosen, 1978). Heterogeneous consumers vary in their willingness-to-pay for quality and their costs to sorting. Specifically, potential consumers have two relevant characteristics—their preference for quality and their cost to sorting—which are defined by some distribution across all potential consumers.

3.1. Modeling Buyers and Demand

Following my earlier work (Ferrier, 2007), M consumers are each price takers with θ_i representing each consumer's preference for quality and λ_i representing their cost of sorting. Consumers collectively are defined by the joint probability distribution $f(\lambda,\theta)$ defined over the strictly positive range of (0,0) and (l,m). Each consumption decision is modeled as a discrete choice to purchase a single good if their indirect utility from purchasing is positive. We assume that consumers who purchase multiple goods are simply represented by multiple points on the distribution and that consumers base their consumption decision on the quality they expect to receive. If no sorting is allowed, all consumers expect to receive quality (q) equal to μ, the average quality of the distribution. If sorting is allowed, each consumer's quality (q_i) depends on average quality μ, on the time or effort a consumer devotes to sorting (t_i), and on the amount of disposal undertaken by the seller (δ, where δ is the percentage of the retail stock sold) so that q_i is equal to $q_i(t_i|\mu,\delta)$.

A consumer's utility function is equal to the value they receive from consuming ($\theta_i \times q_i$) minus the cost of sorting ($\lambda_i \times t_i^2$) minus the price (P).

$$U(\theta_i, \lambda_i, q_i(t_i(\theta_i, \lambda_i)|\mu, \delta)|\mu, \alpha, \delta) = \theta_i q_i(t_i) - \lambda_i t_i^2 - P \tag{1}$$

A larger θ_i indicates a consumer's stronger preference for quality and a larger λ_i indicates a consumer's larger cost to sorting. Both the quality (q_i) and amount of time spent sorting (t_i) are choice variables that depend on θ and λ. Sorting costs are convex to ensure that a finite amount of sorting occurs. More specifically, sorting costs are defined as being quadratic in the amount of time spent by the t^2 term, a functional form which makes analysis far more tractable although somewhat restrictive.

3.2. Modeling Sellers and Supply

Sellers are monopolistic competitors facing the downward sloping demand curve defined by the M possible consumers. Sellers incur a fixed cost in selling and constant marginal costs (c) for each unit of wholesale stock (N), a pattern consistent with a large retail produce store that acquires a wholesale stock and resells it at the retail level. Sellers may precommit to selling only a portion (δ) of their wholesale stock, expecting that only the worst goods remain after consumers sort. Ignoring fixed costs, profits are

$$\Pi(N, \delta, P(N, \delta)|c, \ldots) = (\delta P - c) \times N \tag{2}$$

Importantly, expected quality and all other properties of the distribution are invariant to the size of wholesale stock.

4. SORTING AND DISPOSAL IN MARKETING EQUILIBRIUM

Unsold wholesale stock is obviously costly. Regular and systematic disposal of goods reduces profits unless the act of disposal raises the expected quality of the distribution. Asymmetry of quality information or the inability of sellers to identify key quality characteristics makes seller sorting and the charging of different prices for different qualities impossible. In an earlier work (Ferrier, 2007) I show that sorting can increase seller profits in the absence of disposal if it causes quality discrimination, the strategic distribution of qualities across consumers, without being so prolific that it creates large sorting costs. This model similarly shows that sorting may allow for quality discrimination, but also shows that, with disposal, consumer sorting can allow sellers to raise expected quality. In this sense, precommitting to dispose of a certain percentage of goods is similar to creating a minimum quality standard under grading.

4.1. Quality With Disposal and Consumer Sorting

Logically, one expects that the quality a consumer receives is increasing in her own effort but decreasing in the time spent sorting by other consumers as one consumer's sorting tends to cancel out the other's sorting. For instance, if two consumers both arrive early at a store to beat the other to the better qualities, then they would receive the same quality as if they both arrived simultaneously later in the day.

Let the quality of a consumer's purchase be

$$q_i = q(t_i|t_1, \ldots, t_{i-1}, t_{i+1}, \ldots t_N, \mu, \sigma, \delta) \tag{3}$$

Because each consumer's quality depends on the sorting times of rival consumers, each consumer's choice can be viewed as the Nash equilibrium of a game where consumers simultaneously select sorting times, t_i. In practice, however, large numbers of consumers are unlikely to be able to form expectations of every rival consumer's sort time and instead may rely on a rule of thumb for how time spent sorting affects quality.

Following my earlier work (Ferrier, 2007), a rule of thumb with convenient properties is

$$q_i = q^e(\mu, \delta) + \alpha(t_i - \bar{t}) \tag{4}$$

The variable $\bar{t}$ is the average time that all consumers spend sorting and q^e is the expected quality, conditioned on the portion of goods sold (δ) and average quality (μ). This functional form captures several important features of consumer sorting. First, sorting redistributes qualities, but does not improve them. Second, an increase in the average amount of sorting lowers the quality that any individual consumer expects to receive for any personal level of sorting. Third, sorting can vary in its effectiveness depending on the size of α.

Generally, goods that have a smaller variance in quality are likely to have a smaller value of α and, therefore, a smaller increase in quality for a given amount of time spent on sorting. In this case, consumers will sort less. Also, as discussed previously (Ferrier, 2007), sellers may be able to impact the return to sorting as it affects the distribution of welfare. For example, if sellers package goods to entirely eliminate the consumer's ability to identify quality characteristics, α is zero. Alternatively, sellers may only display a portion of the retail stock on the sales floor. In this case, at any given moment, the number of higher quality goods that might be found by a consumer through sorting is smaller so that α is smaller. Relatedly, when goods have a smaller variance in quality, average quality (q^e) is relatively unresponsive to increases in the amount of disposal (δ).

4.2. The Choice of Sorting Time

Assuming that buyers have correct expectations of α, μ, δ, and $\bar{t}$ and form quality expectations according to the rule of thumb in Equation 6, the optimal sorting time (t_i') is ($\alpha\theta_i/2\lambda_i$) as determined by the first-order conditions.

Proposition 1: *The amount of time a consumer spends sorting is increasing in the effectiveness of sorting* (α) *and the consumer's preference for quality* (θ_i) *and decreasing in the consumer's cost to sorting* (λ_i).

Substituting (t_i') into Equation 1, the consumer's utility is

$$U(t|\theta_i, \lambda_i) = \theta_i\left(q_e + \alpha\left(\frac{\alpha\theta_i}{2\lambda_i} - \bar{t}\right)\right) - \lambda_i\left(\frac{\alpha\theta_i}{2\lambda_i}\right)^2 - P \tag{5}$$

To make a purchase, a consumer must receive a positive utility. After simplification, a consumer's utility is positive when

$$\lambda_i \leq \lambda^D = \frac{\alpha\theta_i}{4\bar{t} - \frac{4}{\alpha\theta_i}(q_e\theta_i - P)} \tag{6}$$

Here, λ^D is a threshold level that defines whether a consumer will purchase when sorting is permitted. When no sorting occurs—so that t_i and $\bar{t}$ equal zero and q_e equals μ—consumer utility is positive if $\theta \geq P/\mu$. Importantly, sorting does not occur either when a marketing mechanism is used to prevent sorting or when goods are uniform so that α is equal to zero. In this case, each individual consumer will choose not to sort even if permitted to do so and disposal is pointless for sellers as it cannot isolate low or high quality goods.

4.3. Equilibrium and Welfare Without Sorting

When sorting is prevented, consumers with θ_i greater than P/μ will make a purchase as they receive a positive utility from purchasing. Using this inequality to define a range of integration, a demand equation is obtained by integrating the joint distribution of consumer preferences in (θ, λ) over all consumers and multiplying by the number of consumers. The demand equation is then:

$$D^{NS}(P) = M \times \int_{P/\mu}^{m} \int_{0}^{l} f(\theta, \lambda) d\lambda\, d\theta = M \times (1 - F(P/\mu)) \tag{7}$$

Substituting in N on the left-hand side of Equation 7, solving for price as $P = \mu F^{-1}(1 - \frac{N}{M})$, and then substituting that price formula to the profit equation in Equation 2 yields a function for profits that depends solely on N. Optimal wholesale stock is specified as follows.

$$N^{NS} = \arg\max_{N} \left(\left(\mu F^{-1}\left(1 - \frac{N}{M}\right) - c \right) \times N \right) \tag{8}$$

Profit and price are then determined from these values

$$\Pi^{NS} = M \times \int_{P^{NS}/\mu}^{m} \int_{0}^{l} (P^{NS} - c) f(\lambda, \theta) d\lambda\, d\theta = \left(\left(\mu F^{-1}\left(1 - \frac{N^{NS}}{M}\right) - c \right) \times N^{NS} \right) \tag{9}$$

$$P^{NS} = \mu F^{-1}\left(1 - \frac{N^{NS}}{M}\right) \tag{10}$$

Similarly, following my earlier work (Ferrier, 2007), the consumer surplus (CS) in Equation 11 is found directly and the deadweight loss (DWL) in Equation 12 is found as the lost benefits to consumers who would have purchased if the good were sold at cost (c) rather than P^{NS}.

$$CS^{NS} = M \times \int_{P^{NS}/\mu}^{m} \int_{0}^{l} (\theta\mu - P^{NS}) f(\lambda, \theta) d\lambda\, d\theta \tag{11}$$

$$DWL^{NS} = M \times \int_{c/\mu}^{P^{NS}/\mu} \int_0^l (\theta\mu - c) f(\lambda, \theta) d\lambda \, d\theta \tag{12}$$

These formulas provide a baseline with which to compare profits and welfare in the equilibrium where sorting and disposal do not occur to the equilibrium in which they do.

4.4. Equilibrium and Welfare With Sorting and Disposal

When sorting is allowed, consumers with λ_i less than λ^D will make a purchase. Again, a demand equation is obtained by integrating the joint distribution of consumer preferences in (θ, λ) over consumers with λ less than λ^D and multiplying by the number of consumers. Noting that λ^D is a function of P and δ, demand is

$$D(P, \delta) = M \times \int_0^m \int_0^{\lambda^D} f(\lambda, \theta) d\lambda \, d\theta \tag{13}$$

Substituting Equation 13 into Equation 2, profit is a function of P and δ with optimal values at

$$[P^D, \delta^D] = \arg\max_{P,\delta} \left[(\delta P - c) \times M \times \int_0^m \int_0^{\lambda^D} f(\lambda, \theta) d\lambda \, d\theta \right] \tag{14}$$

Similarly, equilibrium wholesale stock purchases can be found as follows:

$$N^D = \frac{1}{\delta^D} \left[M \times \int_0^m \int_0^{\lambda^D} f(\lambda, \theta) d\theta \, d\lambda \right] \tag{15}$$

and profits can be found through direct substitution. As when sorting is prevented, the consumer surplus (CS), sorting costs (SC), and deadweight loss (DWL), where λ^C is the λ threshold value defined by Equation 6 where price is equal to the net cost with disposal (c/δ), are as follows:

$$CS^D = M \times \int_0^m \int_0^{\lambda^D} \left(\theta \left(q^D + \alpha \left(\left(\frac{\alpha\theta}{2\lambda} \right) - \bar{t} \right) - \lambda \left(\left(\frac{\alpha\theta}{2\lambda} \right)^2 \right) - P^D \right) \right) f(\lambda, \theta) d\lambda \, d\theta \tag{16}$$

$$DWL^D = M \times \int_0^m \int_0^{\lambda^C} \left(\theta\mu - \frac{c}{\delta} \right) f(\lambda, \theta) d\lambda \, d\theta - M \times \int_0^m \int_0^{\lambda^D} \left(\theta\mu - \frac{c}{\delta} \right) f(\lambda, \theta) d\lambda \, d\theta \tag{17}$$

$$SC^D = M \times \int_0^m \int_0^{\lambda^D} \lambda \left(\frac{\alpha\theta}{2\lambda} \right)^2 f(\lambda, \theta) d\lambda \, d\theta \tag{18}$$

The quality change imparted to each consumer in this equilibrium can be decomposed into two parts. Disposal creates a general net benefit to every consumer by improving quality. The magnitude of this gain is found by multiplying the average change in quality under disposal $(q_e - \mu)$ by each consumer's preference for quality. This benefit is the disposal quality benefit, DIS^D.

$$DIS^D = M \times \int_0^m \int_0^{\lambda^D} \theta (q_e - \mu) f(\lambda, \theta) d\lambda \, d\theta \tag{19}$$

Simultaneously, consumer sorting redistributes qualities across the consumers because each consumer sorts with different levels of intensity. If this redistribution results in better qualities going to consumers who value them more, then a quality efficiency gain occurs. Conversely, if low value consumers receive higher qualities, then a quality efficiency loss occurs. In my previous publication (Ferrier, 2007), I argue that, without disposal, a redistribution that facilitates quality discrimination and causes a quality efficiency loss is necessary for profits to increase with sorting. With disposal, quality discrimination is not necessary. Sorting can increase profits if the disposal quality benefit is sufficiently large despite an undesired redistribution. Equation 20 defines the quality efficiency gain (or loss; *QEG*) as:

$$QEG^D = M \times \int_0^m \int_0^{\lambda^D} \theta\left(\alpha\left(\frac{\alpha\theta}{2\lambda}\right) - \bar{t}\right) f(\lambda, \theta) d\lambda \, d\theta \tag{20}$$

This term is the sum of the net differences in quality that results from each consumer's sort time relative to the average sort time multiplied by that consumer's valuation of quality.

Proposition 2: *When consumers with heterogeneous sorting costs and quality preferences sort goods, the total gains to trade decrease by the sorting costs and the quality efficiency loss and increase by the disposal quality benefit.*

5. SIMULATIONS RESULTS OF WELFARE WITH AND WITHOUT DISPOSAL

Solving for parametric solutions to the welfare measures is complicated by the fact that $\bar{t}$, the average time spent sorting, is endogenously determined. In general, unless extreme restrictions are placed on the distribution of preferences and sorting costs, a tractable solution cannot be easily found. Simulations, however, can be used to demonstrate the general properties of the alternative equilibrium and the feasibility of disposal as a way of increasing profits.

To simplify the simulations, quality is assumed to be uniformly distributed over the range $\{\mu - n, \mu + n\}$ so that average quality with disposal (q^e) is $\mu+(1-\delta)n$. In this specification, as the variance of quality rises, the expected changed in quality from disposal also increases, thus increasing the returns to disposal among sellers.

Proposition 3: *Sellers increase disposal rates as the variance in quality rises.*

Conveniently, the specification of t' makes the consumer's choice of sorting time independent of expected quality (q_e). For this reason, the amount of time a consumer spends sorting, their sorting cost, and their quality efficiency loss is unaffected by changes in the variance in quality around the average quality (determined by n). This allows for a rather straightforward comparison of profits and optimal disposal time as the variance in quality changes. Admittedly, this obscures a potentially important linkage between α, the return to sorting, and n, the range of quality. In many cases, if the range in quality falls (n), consumers are likely to view the return to sorting (α) as being smaller. However, sellers can also potentially reduce the returns to sorting through packaging or distribution without reducing the underlying distribution of quality.

Simulations results are presented in Tables 2 and 3 that compare welfare and profits when sorting and disposal are used under different levels of quality variance. Table 2 presents profits and welfare for a baseline case where $\alpha = 0.5$ and $\mu = 5$ and eight equal-sized consumer groups[2] have the θ_i and λ_i shown. In these simulations, the time spent sorting is determined endogenously, being both invariant to price and the amount of disposal, while α, μ, θ, and λ are assumed to be exogenous. Three scenarios are presented: (a) where no sorting is allowed, (b) where sorting is allowed but no disposal occurs, and (c) where sorting and disposal both occur. In each case, the equilibrium price and disposal rates are set to their optima. Under sorting, the equilibrium quantity rises from 4 to 5 and the price falls from 40 to 36.4. Once 10% of the wholesale stock is disposed of ($\delta = 0.9$), the price then rises to 38.85 along with profits which move from 82 to 83.14. In this simulation, the distribution of θ defines a linear demand curve and the λ-values were chosen to be correlated with θ to allow for the quality discrimination outcome consistent with the practice of sorting being profitable (without any disposal). As mentioned earlier, quality discrimination is not necessary for disposal to increase profits.

Table 3 presents the same baseline case in Table 2 and scenarios in which the variance in quality (n) is larger and smaller. In each, profits are larger when some disposal occurs. In the second case, when n (a proxy for quality variation) shrinks from 3.5 to 3.125 relative to the baseline, the price under disposal falls from 38.85 to 37.29 and the percentage of the good discarded ($1-\delta$) falls from 10 to 4%. Price falls as disposal decreases and expected quality (q_e) falls as fewer goods are discarded with sellers reducing disposal costs. As the variability of quality increases relative to the baseline, the reverse occurs. An increase in n from 3.5 to 4 causes an increase in the price from 38.85 to 40.6 and the percentage of the good discarded to rise from 10 to 15%. In each case, disposal raised expected quality with the effect of raising prices and consumer surplus. These simulations confirm the simple intuition that increasing the return to disposal results in more goods being thrown out as stated in Proposition 3.

6. COMPARATIVE STATICS UNDER THE SPECIAL CASE OF DISCRETE SORTING

It is instructive to characterize situations in which disposal is profitable when sorting is discrete and the distribution of (λ, θ) is joint uniform. As with continuous sorting, some disposal by the seller is more likely to be profitable when the marginal impact of disposal on average quality is larger. Under discrete sorting, each consumer sorts for the same amount of time and has the same expected quality when they do. In this case, sorting may be viewed as the simple exercise of consumers ignoring goods in the lowest part of the quality distribution, but not necessarily being able to distinguish qualities which are the best.

Under discrete sorting, consumers sort ($t = 1$) or do not sort ($t = 0$). Again, let q_e represent the expected quality of goods and δ represent the percentage of goods sold.

[2]In the simulations, consumer groups are discrete, but the amount of disposal is continuous. If groups size are very small (one consumer in each group) then a fractional disposal level seems nonsensical as a fractional level of goods being sold. This paper assumes that consumer groups are sufficiently large, so that any disposal level might be chosen without concern for fractions.

TABLE 2. Simulated Profits and Welfare With No Sorting, Sorting and No Disposal, and Sorting and Disposal ($\mu = 5$)

					No sorting ($P = 40$, $\delta = 1$, $\Pi = 80$)		Sorting, no disposal ($P = 36.4$, $\delta = 1$, $\Pi = 82$)			Sorting, disposal ($P = 38.85$, $\delta = 0.9$, $\Pi = 83.14$)			
Consumer	θ_i	λ_i	t_i	Sort cost	Surplus	DWL	Qual.	Surplus	QEG	Qual.	Surplus	QEG	DIS
1	**11**	**6**	0.46	**2.75**	**15.00**	0.00	4.80	**13.67**	**−2.15**	5.15	**15.10**	**−2.15**	**3.85**
2	**10**	**4**	0.63	**2.50**	**10.00**	0.00	4.89	**9.98**	**−1.13**	5.24	**11.03**	**−1.13**	**3.50**
3	**9**	**3**	0.75	**2.25**	**5.00**	0.00	4.95	**5.90**	**−0.45**	5.30	**6.60**	**−0.45**	**3.15**
4	**8**	**3**	0.67	**2.00**	**0.00**	0.00	4.91	**0.87**	**−0.73**	5.26	**1.22**	**−0.73**	**2.80**
5	**7**	**1**	1.75	**1.75**	−5.00	**15.00**	5.45	**0.00**	**3.15**	5.80	**0.00**	**3.15**	**2.45**
6	**6**	**0.7**	2.14	1.50	−10.00	**10.00**	5.65	−4.02	3.88	6.00	−4.37	3.88	2.10
7	**5**	**0.8**	1.56	1.25	−15.00	**5.00**	5.36	−10.87	1.78	5.71	−11.57	1.78	1.75
8	**4**	**1**	1.00	1.00	−20.00	**0.00**	5.08	−17.10	0.30	5.43	−18.15	0.30	1.40
Sums				\$11.25	\$30.00	\$30.00		\$30.44	\$−1.31		\$33.94	\$−1.31	\$15.75

Note. Bold values were included in sums. DWL = Deadweight loss; QEG = quality efficiency gain; DIS = disposal quality gain.

TABLE 3. Simulated Profits and Welfare With and Without Disposal as the Variance in Quality (n) Changes ($\mu = 5$)

		$n = 3.5$, $\delta = 0.9$		$n = 3.125$, $\delta = 0.96$		$n = 4.0$, $\delta = 0.85$	
	No sorting	Sorting, no disposal	Sorting, disposal	Sorting, no disposal	Sorting, disposal	Sorting, no disposal	Sorting, disposal
Number of consumers	4	5	5	5	5	5	5
Price ($)	40	36.40	38.85	36.40	37.29	36.40	40.60
Percent sold (%)	100	100	90	100	96	100	85
Cost per unit sold ($)	20	20.00	22.22	20.00	20.83	20.00	23.53
Total gains to trade ($)	140	130.35	139.54	130.35	139.54	130.35	139.54
Profit ($)	80	82.00	83.14	82.00	82.28	82.00	85.35
Total revenue ($)	160	182.00	194.25	182.00	186.45	182.00	203.00
Total product cost ($)	80	100.00	111.10	100.00	104.17	100.00	117.65
Disposal costs ($)	0	0.00	10.00	0.00	4.17	0.00	4.17
Consumer surplus ($)	30	30.44	33.94	30.44	19.31	30.44	36.44
Qual. eff. gain (QEG) ($)	0	−1.31	−1.31	−1.31	−1.31	−1.31	−1.31
Disp. qual. gain (DIS) ($)	0	0.00	15.75	0.00	5.72	0.00	27.00
Sorting cost ($)	0	11.25	11.25	11.25	11.25	11.25	11.25
Deadweight loss (DWL) ($)	30	17.91	22.46	17.91	19.31	17.91	26.21

Consumers will now purchase a sorted good if they receive a positive utility so that

$$\theta_i q_e - \lambda_i - P \geq 0 \tag{21}$$

$$\theta_i \geq (\lambda_i + P)/q_e \tag{22}$$

As before, let $(\delta P - c)N$ be the retailer's profits and let disposal and quality preferences and sorting costs (λ, θ) be distributed joint uniformly between (0,0) and (l, m). Disposal increases quality which increases the quantity demanded at any given price. The quantity demanded is simply the number of potential consumers multiplied by the probability mass of the area where θ is greater than $(\lambda + P)/q_e$ but less than m. Assuming that $l > m - (P/q_e)$, demand as a function of price is then $(M/2\ ml)(m - (P/q_e))^2$. The quantity supplied is the wholesale volume multiplied by the disposal rate or δN.

Equation 23 below represents this supply and demand equality

$$\delta N = (M/(2ml))(m - P/q_e)^2 \tag{23}$$

Because 23 is strictly positive, the negative root is trivial. Solving for price in the positive root yields:

$$P = q_e m - \sqrt{((2ml\delta N q_e)/M)} \tag{24}$$

Substituting the price in Equation 24 back into the profit function enables profit to be expressed solely as a function of N and q_e.

$$\Pi = (\delta q_e m - \delta \sqrt{((2ml\delta N q_e)/M)} - c) \times N \tag{25}$$

Sellers optimize profits in a partial equilibrium by solving the first-order conditions with respect to N assuming a fixed level of δ. Importantly, q_e is constant because increasing the amount sold, N, does not influence expected quality:

$$\partial \Pi(N, \delta)/\partial N = \delta(q_e m - \sqrt{(2ml\delta N q_e)/M}) - c - \delta N(\sqrt{(\delta m l q_e)/(2NM)}) = 0 \tag{26}$$

$$N^D = (2M/(9\delta q_e ml)) \times (q_e m - c/\delta)^2 \tag{27}$$

This quantity, N^D, can then be substituted back into the Equation 24 for a convenient form of prices:

$$P^D = \left(\tfrac{1}{3}\right) q_e m + \left(\tfrac{2}{3}\right)(c/\delta) \tag{28}$$

Finally, with P^D and N^D, profits can be expressed as a function of q_e and δ:

$$\Pi^D = (2M/(27ml q_e)) \times (q_e m - c/\delta)^3 \tag{29}$$

Because the known distribution of quality is invariant to wholesale volume, N, the expected quality, q_e, is exactly defined if θ is known. Profits, in Equation 29, are solely a function of the choice variable δ and the exogenous market parameters M, m, l, and c.

The optimal level of disposal (δ^D) is obtained by solving the first-order conditions of the profit function. This condition is

$$\partial\Pi^D/\partial\delta = \frac{2M}{27ml}(q_e m - c/\delta)^2(-q_e'/(q_e)^2(q_e m - c/\delta) + 3/q_e(q_e' m + c/\delta^2)) = 0 \tag{30}$$

After simplification, Equation 30 is $(\delta^2 + (q_e c/2m)\delta + 3c/(2mq_e')) = 0$. In addition to the trivial double root that solves $(q_e m - c/\delta)$ equal to zero,[3] Equation 30 has the solutions:

$$\delta^D = q_e c/4m \pm \sqrt{\tfrac{1}{8}(q_e c/m)^2 - \tfrac{3}{2}(c/q_e' m)} \tag{31}$$

The variable q_e' is the marginal effect of a change in disposal on expected quality, or $\partial q_e/\partial\delta$. Both q_e and q_e' are functions of δ^D and q_e' is negative because as less of the total supply is sold, the average quality of any single unit sold increases. Unfortunately, it is difficult to explicitly derive parametric solutions for Equation 30 even when severe restrictions are placed on the distribution of quality.[4]

However, as long as the marginal effect of δ on profits is negative when all goods are sold, *some* disposal will increase profits. In terms of Equation 30, disposal increases profits if $(\partial\Pi/\partial\delta) \leq 0$ when no disposal occurs (that is, $\delta = 1$). In this case, the marginal effect of a change in disposal is

$$\frac{\partial\Pi^D}{\partial\delta} = c(q_e'/q_e) + 2q_e' m + 3c \leq 0 \tag{32}$$

In relationship to wholesale costs, c, some disposal increases profits if

$$c \leq -2q_e' q_e m(q_e' + 3q_e)^{-1} \tag{33}$$

The Appendix shows that for any finitely bounded distribution, the denominator of Equation 33 is positive as long as disposal is less than two thirds. In this case, because q_e' is negative, the right-hand side of Equation 33 is negative.

Proposition 4: *Disposal is more likely to be profitable when wholesale costs are lower or when the marginal effect of disposal on quality increases.*

As c falls or q_e' rises, Equation 33 is more likely to hold and disposal is more likely. Additionally, as m increases, disposal is more likely. Because m can be interpreted as the range of consumer preferences for quality, this suggests that disposal is more profitable as consumer preferences become more heterogeneous, but this finding may be specific to consumer tastes being uniform because increasing m also increases the average consumer preference for quality ($m/2$) as well.

Alternatively, the optimal level of disposal expressed in Equation 30 can be expressed in terms of the elasticity of the equilibrium quantity under disposal with respect to disposal rates, $\varepsilon_{N,\delta}$, and elasticity of price with respect to disposal rates, $\varepsilon_{P,\delta}$, in Equation 34.

$$\partial\Pi/\partial\delta = (\delta P - c)(\partial N/\partial\delta)(\delta/N) + (1 + (\partial P/\partial\delta)(\delta/P))\delta P = 0 \tag{34}$$

$$\delta^D = (c/P)(\varepsilon_{N,\delta}/(\varepsilon_{N,\delta} + \varepsilon_{P,\delta} + 1)) \tag{35}$$

[3]The solution for this root always sets profit equal to zero and can thus be ignored.

[4]Even when quality is uniformly distributed, the optimal level of disposal is the root to a cubic equation.

The elasticities $\varepsilon_{N,\delta}$ and $\varepsilon_{P,\delta}$ can both be expected to be negative. The quantity elasticity, $\varepsilon_{N,\delta}$, is negative because as sellers discard fewer goods (δ *increases*), they require less wholesale supply (N *decreases*). The price elasticity, $\varepsilon_{P,\delta}$, is negative because as sellers discard fewer goods (δ *increases*), the expected product quality drops and the price falls (P *decreases*).

Proposition 5: *As the price–cost ratio increases* (c/P *approaches zero*), *disposal also increases* (δ^D *approaches zero*).

To the extent that disposal increases the price firms can charge, disposal is more profitable when markups over wholesale prices are high or simply when wholesale costs are low. These findings are consistent with the observation that convenience stores throw out more food than grocery stores assuming that convenience stores have larger markups.

Proposition 6: *When price is more responsive to changes in disposal rates* ($\varepsilon_{P,\delta}$ *is larger in absolute value*), *the level of disposal also increases* (δ^D *approaches zero*).

Holding the amount sold constant, price is more responsive to changes in disposal rates when the distribution of quality is skewed so that there are only a few items of very low quality.

7. CONCLUSION

Barzel (1977, 1982) argues that sellers will bundle goods to prevent consumers from sorting goods because the added costs of sorting do nothing to enhance the gains from trade. Using comparative statics and simulations, this article shows that retailers may allow consumer sorting as a way of raising average quality. Retailers are more likely to use disposal to raise the expected quality of goods when wholesale costs are low, when markups are high, and when a small increase in disposal greatly increases the expected quality of a good. This finding contrasts with implication of the theory of "shipping the good apples out" where higher transactions costs cause consumers to substitute towards higher quality products by lowering their opportunity cost in terms of lower quality goods. In this model, higher cost and lower retail markups make disposal more expensive and subsequently lower the average quality of the goods actually sold.

Although disposal might initially be considered waste from the standpoint of goods not being consumed, this article shows that disposal may be viewed as a quality improvement mechanism and planned by retailers. Stiglitz (2002) argued that information asymmetries can lead to situations where markets with fully flexible prices do not clear. This article provides another example of when the entirety of a wholesale stock might go unsold in the presence of asymmetric information. In this context, unsold goods should not necessarily be considered as overproduction or waste.

APPENDIX

The denominator in Equation 32 is only positive if $|q_e'| < 3q_e$ where q_e' is $\partial q_e/\partial\delta$. This is always the case when disposal consists of less than two thirds the retail stock and qualities are finite. Recall that δ is the percentage sold and $(1-\delta)$ is the percentage discarded. A reduction in δ causes the greatest increase in expected quality if quality is distributed binomially, which I will assume now. Let π be the probability of high quality, qH, and $(1-\pi)$ be the probability of the low quality, q_L. Expected quality without disposal is

$$q_e = \pi q_H + (1-\pi)q_L = q_L + \pi(q_H - q_L) \tag{A1}$$

With disposal, expected quality is

$$q_e = \frac{\pi q_H + (1-\pi-(1-\pi))q_L}{\delta} = q_L + \frac{\pi}{\delta}(q_H - q_L) \tag{A2}$$

In this case,

$$q_e' = \frac{\partial q_e}{\partial \delta} = -\frac{\pi}{\delta^2}(q_H - q_L) \tag{A3}$$

So, the denominator term from Equation 34 is positive if $|q_e'| < 3q_e$ or, equivalently, if

$$q_e' + 3q_e \geq 0 \tag{A4}$$

This is the case if

$$-\frac{1}{\delta^2}\pi(q_H - q_L) + 3q_L + 3\frac{1}{\delta}\pi(q_H - q_L) \geq 0 \tag{A5}$$

Temporarily, assume that q_L is zero. In this case,

$$-\frac{1}{\delta^2}\pi(q_H - q_L) + 3\frac{\pi}{\delta}(q_H - q_L) \geq 0 \tag{A6}$$

or

$$-\frac{1}{\delta} + 3 \geq 0 \quad \text{or, equivalently,} \ \delta \geq \frac{1}{3} \tag{A7}$$

Therefore, as long as sellers do not throw out more than two thirds of their retail stock $(1-\delta)$, then $(q_e' + 3q_e)$ in Equation 32 is positive. If q_L is greater than zero or if the quality distribution is not binomial, then δ would need to be even smaller for the denominator to be negative (in other words, the seller would have to throw out even more than two thirds).

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Peyton Ferrier *is an economist with the Market and Trade Economics Division of the USDA's Economic Research Service. He received his PhD in Economics from North Carolina State University in 2004. His research interests include demand analysis, product differentiation, SPS measures, and agricultural supply chains.*